LCA Case Studies

The HoVe Assessment Method: Principal Structure and Pilot Application

Assessing "High Quality" and "Environmental Soundness" of Waste Treatment and Disposal Plants According to the Requirements of the German Waste Avoidance, Recovery and Disposal Act

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Abstract

The German Waste Avoidance, Recovery and Disposal Act (KrW-/AbfG) creates the demand to select for "high quality" and "environmentally sound" waste treatment and disposal techniques. Waste disposers have to choose the most "high quality" and "environmentally sound" technique among different treatment and disposal options, and therefore must have a way to comparably evaluate the different techniques. Prognos developed an assessment method called HoVe to evaluate waste treatment and disposal facilities based on these new guidelines. It adheres to international standards of life cycle assessments (DIN/ ISO 14 040). The assessment is based on emission, material, energy and economic data which already exists, making it practical, time and cost efficient.
HoVe employs three Impact Categories (IC) to evaluate the impact of waste treatment. Each IC is characterized by Impact Clusters (ICL) to which original plant data are allocated. The ICL consider the amount and quality of produced products and residues from treatment processes, as well as the issues of ecological impact and energy balance. Further they incorporate economic aspects in order to assess the economic soundness of treatment and disposal plants, a requirement of the KrW-/AbfG. A pilot assessment of treatment options for shredder residues proves the viability of the method.

Keywords: Closed circuit system; disposal plants; environmental assessment; environmentally sound waste treatment; high quality waste treatment; KrW-/AbfG; LCA; Life Cycle Assessment; material flow management; plant assessment; resource preservation; waste treatment plants

1 Introduction

The idea of sustainability has become increasingly important in environmental science and politics in recent years. Advances include: developments in Life Cycle Assessments (LCA), concepts of cleaner production, and new political regulation [1]. The German Waste Avoidance, Recovery and Disposal Act (Kreislaufwirtschafts- und Abfallgesetz – KrW-/AbfG), which came into effect on October 7th, 1996 is an example of a regulation, that tries to improve the use of resources by guiding waste flow. It formulates the demand for "environmentally sound" treatment and disposal technologies and "high quality" recycling in waste management. The act continues the hierarchical solid and liquid waste strategy of avoidance, reuse and disposal (§ 4). It allows the external treatment or disposal of waste, if waste avoidance is not possible or not economically feasible. In the case of recycling, waste producers and disposers must choose plants, that offer "high quality" recycling for each specific kind of waste. (§ 5 par. 2). Further, the KrW-/AbfG formulates a demand to choose the most "environmentally sound" treatment or disposal process (§ 5 par. 5)[1].

The legal term "high quality" in the KrW-/AbfG refers to waste treatment options, which lead to the highest possible resource conservation through the reuse of waste on a high quality level. A specific definition does not exist. "Environmental soundness" is not specifically defined either, nor is there a concept to evaluate waste treatment and disposal plants[2].

HoVe was developed by Prognos to create a standardized method based on the requirements of the KrW-/AbfG for "environmentally sound" and "high quality" disposal techniques. To do this, Prognos defined the terms "environmen-

[1] According to the KrW-/AbfG, waste recovery may not be chosen when the disposal of waste is the more environmentally sound solution.

[2] The KrW-/AbfG only gives four points that must be considered in the allocation of waste disposal or recovery and which could be used in the general evaluation of waste treatment processes: expected emissions; conservation of natural resources; energy consumed or yielded; and the resultant increased accumulation of harmful substances in products, waste for recycling, or in products made from such recycled materials.

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tally sound" and "high quality"[3]. HoVe (Hochwertige Verwertung) delivers a methodological approach to:

(1) quantify and evaluate the recovery of waste and its contribution to resources conservation and

(2) comparably assess the environmental impact of waste treatment plants for specific kinds of waste.

HoVe's target is also to reach a high political and societal acceptance level. It is therefore a comprehensible, economically efficient and application-oriented method [2]. HoVe adheres to the international principals for Life Cycle Assessments [3,4]. In the following article the method is described with focus on particularly innovative developments in assessing product and waste cycles. A Prognos pilot assessment of treatment options for shredder residues proves the viability of the method and presents an application example.

2 Method Structure

The HoVe method is a modification of existent Life Cycle Assessment methods [5, 6]. Its evaluation steps are: Goal Definition, Inventory, Classification and Characterization, Normalization and Valuation.

2.1 Goal and scope definition

The evaluation target is to contrast treatment plants to determine which are the most "high quality" and "environmentally sound", taking economic aspects into account. HoVe fulfills the demands of the KrW-/AbfG.

The principle scope and conventions of HoVe are:

- German and European Community laws are complied with by the plant operators
- the assessment is based on material, energy and economic data that already exist
- the assessment is waste specific[4]
- the different treatment options are evaluated in relation to each other
- only plants that already exist on the market or reach a marketable stage as a pilot or laboratory plant will be evaluated. Data of plant operation must be available
- the waste input acts as a functional unit. Impacts and flows are related to one metric ton of waste input
- it is assumed that there is a market for any product or waste for recovery produced by waste treatment plants[5]
- the impact of the construction and usage of the goods that have become wastes are not considered in the evaluation
- waste transport is not considered.[6]

Figure 2.1 shows the total material and energy flow, which HoVe considers.

2.2 Inventory step

Prognos has defined three Impact Categories (IC) to evaluate the impact of waste treatment and disposal plants: Material Flow Quality (MFQ), Economic Efficiency (EE) and Ecology (E). Each IC is characterized by Impact Clusters (ICLs) to which original plant data are allocated.

Impact categories: are significant ecological, material and economic fields which might be influenced by waste treatment and disposal processes

Impact clusters: characterize the impacts of the treatment or disposal processes on the Impact Categories

Indicators: normalize the impact of different substances within the Impact Clusters of the impact category Ecology

2.2.1 Impact category: Material Flow Quality (MFQ)

The IC Material Flow Quality fulfills the requirements of the KrW-/AbfG to assess

[3] The legal terms "environmentally sound" (umweltverträglich) and "high quality" (hochwertig) are not defined in the KrW-/AbfG. In order to implement this new law it is necessary to define these terms. Through HoVe's methodological structure, Prognos provisionally defines "high quality" and "environmental sound" waste treatment facilities. The definitions are in close alignment with the KrW-/AbfG's requirements. While the German government bears the right to responibility officially define these terms, Prognos suggests that our definitions might serve a good basis to do so.

[4] Wastes are defined according to the German (after 1999 the European) Index of Waste. In general, input waste is assumed to have a defined composition.

[5] German law defines "products" as goods when the main goal of the plant is their production. Wastes for recycling or secondary resources are the other marketable output material flows of waste treatment facilities.

[6] Prognos decided to exclude the environmental impacts related to the transport of waste, because HoVe should present a general view on waste treatment options. The specific waste is largely produced in different areas and is dispersed over the country. The treatment or disposal facilities are or could be built at various locations, depending upon economic demand. Therefore, it is usually not relevant to consider the environmental impact of the waste transport. In applications where transport processes seem to be relevant, the assessment of these systems could be easily added as external module.

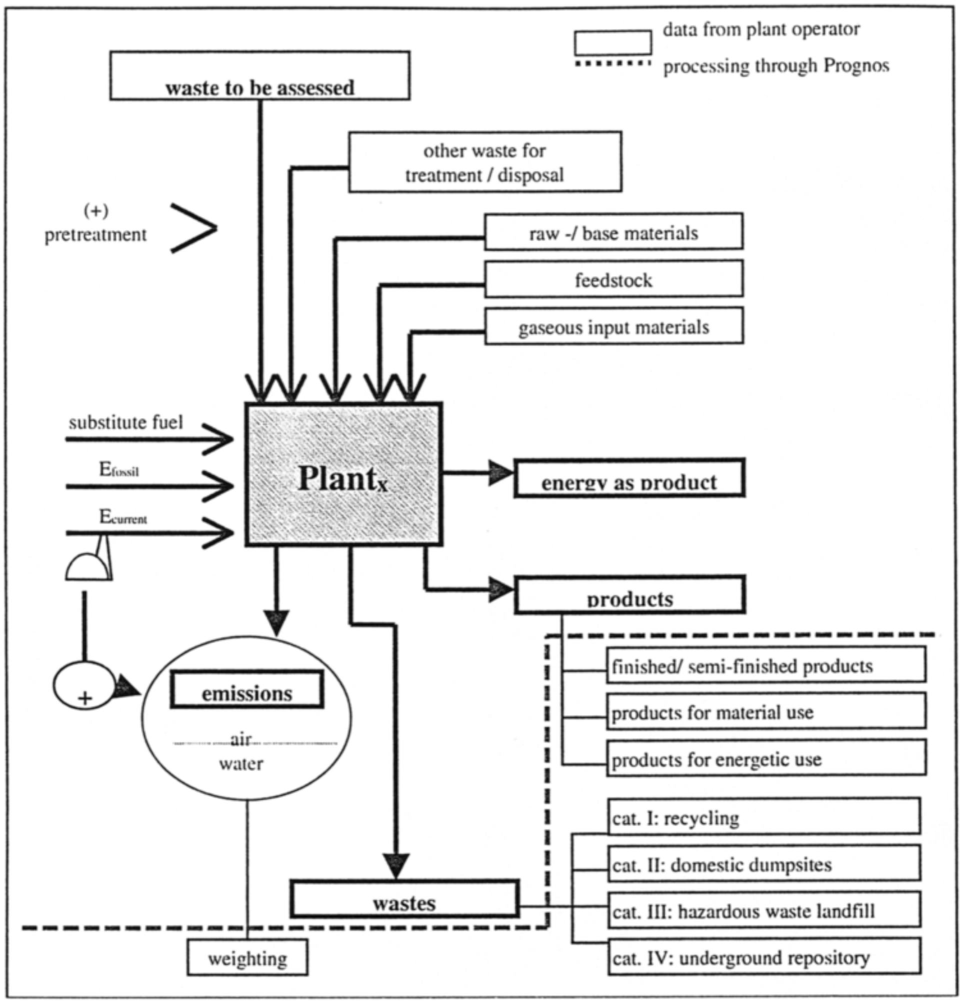


Fig. 2.1: Material flow graphic of the HoVe assessment method © prognos. Efossil = Energy input fossil fuel; Ecurrent = Energy input electrical Energy

1. resource preservation
2. closed-circuit options and
3. harmfulness of output materials[7].

The input waste can be converted into energy, products, residues and/or emissions. Energy, fresh water and clean air are needed for this conversion. The IC Material Flow Quality evaluates the substance flow and resources needed or conserved by the plant operation.

Ad 1: HoVe evaluates the resource preservation based on the material cycle and energy balance of the treatment processes. HoVe uses ICLs (fresh) *Water Consumption* (WV), (clean) *Air Consumption* (LV) and (effective) *Energy Rate* (EReff) to analyze the effects on natural resources. The effective *Energy Rate* is a balance of energy flow. It considers the energy content of the input waste(s) and base materials, the primary energy consumption and any energy produced by the plant. If electric current is used for treatment, the emissions resulting from the electric power generation are added. If the plant produces electricity, the equivalent emissions are subtracted in the IC Ecology

Further, HoVe defines the ICL *Substitution Rate* (SR) for solid/liquid and gaseous products as the percentage of the products of plant operation that is formed by the input waste thus replacing primary resources. By definition energy is also a product and a *Substitution Rate* is defined for it. In order to compare the energy recovery in material flow equations, the amount of produced energy is converted into coal equivalent. This ensures that the energetic use of waste can be compared with material recycling. The *Substitution Rate* is defined as zero if there is no product of a treatment process.

Ad 2: HoVe defines the ICLs *Output Rate* (OR) and the *Product Quality* (PQ) to assess the closed-circuit systems of

[7] Therefore it could indicate the "higher quality" of a plant, also this term is not finally defined. Some aspects of LCA, such as energy balance, are allocated within the IC Material Flow Quality.

waste treatment plants. The *Output Rate* measures the amount of product per metric ton of treated waste and indicates the efficiency of material recycling or energy recovery. The *Product Quality* assesses the quality of the resultant products. Prognos has defined a list of refining chains for significant products, including the main intermediate products. The resulting products are ranked according to their product refining chain level and are matched with pre-defined weighting factors[8].

Ad 3: The ICLs *Waste Output Rate* (AR) and *Waste Quality* (AQ) consider the amount and quality of the residues from the waste treatment processes. Maximum waste diminution improves plant evaluation. The *Waste Output Rate* is the ratio of output residues to input wastes and thus indicates the conversion efficiency of a treatment or disposal plant.

The *Waste Quality* is defined through a ranking of the residues according to their harmfulness. The ranking complies with the German "Technical Guidance – Waste" (TA Abfall)[9], plus a category "waste for recycling". Thus there are four classes of waste quality. In accordance with KrW-/AbfG wastewater is also included.

2.2.2 Impact category: Ecology (E)

The IC Ecology is based on current life cycle assessment methods [3,7,8,9] and will not be discussed in detail. Prognos uses eight ICLs, covering the environmental impact of global significance, ecotoxicological impact and human risk (ÖZs). The list of ICLs is based on the standards of SETAC [9]. The allocation of emissions data to ICLs is based on two conditions:

1. substances are relevant in causing a specific environmental damage
2. substances must be monitored because of federal guidelines; thus data on them already exists.

From lists of priority substances (UBA, OECD) Prognos has chosen those which are monitored under the 2nd and 17th Federal Ambient Pollution Control Ordinance (2. + 17. BimSchV), the German Clean Air Directive (TA Luft) or the Waste Water Tax Act (AbwAG). This enables plant operators to deliver data without supplemental costs. In general the emission freights per ton of treated waste are taken into account.

[8] Energetic products and thus the coal equivalent for example is set equal to coal ore. Both are wheighted with the factor 0.2. The best possible wheigting factor is 1.0.

[9] It characterizes the waste according to their assigned disposal techniques: Waste requiring surveillance for underground repositories; waste requiring surveillance for dumps for hazardous waste; waste requiring surveillance for either domestic dump sites or dumps for hazardous waste (depending on waste contamination); waste of residential type for domestic dump sites.

Table 2.1: Impact Cluster of the Impact Category Ecology, allocated emissions

Impact Cluster	Allocated emissions
Global Warming (ÖZ gw)	CO_2
	NOx
	Halogenated hydrocarbon
Ozone Depletion (ÖZ od)	Halogenated hydrocarbon
	NOx
	Tetrachloromethan
Low-lying Ozone Creation (ÖZ oc)	Volatile Organic Contaminants
	Organic Compounds, par. 3.1.7 TA Luft
	Benzol/ 1,3-Butadien
Acidification (ÖZ acid)	NOx
	SO_2
	HCl
Eutrophication (ÖZ eutro)	P
	N
Water Route Toxicity (ÖZ toxwa)	Chemical Oxygen Demand
	Adsorbed Organic Halogens
	Hg, Cd, Cr, Ni, Pb, Cu
	Fish toxicity
Air Route Toxicity (ÖZ toxair)	Hg
	Cd / Tl
	Σ Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn
	PCDD / PCDF
Carcinogenicity (ÖZ carc)	PCDD / PCDF
	Substances according par 2.3 TA Luft

HoVe uses weighted emission freights to evaluate the environmental impact of plant emissions. Each ecological IC is normed on one lead indicator. When available, **HoVe** uses accepted concepts to identify lead indicators such as: General Warming Potential (GWP, normalized on CO_2-emission), Ozone Depletion Potential (ODP) or Photochemical Ozone Creation Potential (POCP) for the normalization of the ICLs. The emissions of the ICL *Air Route Toxicity* are normed on German MAK-Values (Maximum Workplace Concentration), the *Water Route Toxicity* is normed on the threshold values of the German Waste Water Tax Act and the *Carcinogenicity* is normed on threshold values of the Clean Air Act (→ *Table 2.1*). The lead indicators (Hg, Cd, PCDD/F) are set equal to the number one. Other Emission freights are reduced with the weighting factors derived from the ratio of their threshold value to the threshold value of the lead indicator. Using threshold values makes it possible to easily modify normalization bases to comply with guidelines of other countries.

2.2.3 Impact category: Economic Efficiency (EE)

The KrW-/Abfg demands economically feasible solutions and therefore requires a method to evaluate and compare the costs and benefits of treatment options. Furthermore, potential solutions should be environmentally **and** economically sound to be implemented. **HoVe** considers economic aspects in the evaluation.

Two ICLs within the IC Economic Efficiency make it possible to account for economic factors. The ICL *Economical Feasibility* (WZ) evaluates the cost of treatment or disposal plants compared to the costs of presently used disposal options for a specific kind of waste. The ICL *Economic Benefits* (WE) evaluates the quality and market value of recycling products. The proceeds obtained from these secondary products are related to the scarcity of primary resources and the economic demand [10]. Thus, profits from product sales act as an indicator for the quality of products and also shows the market position of treatment facilities.

3 Process of Evaluation

The original data about the material flow, energy balance and emissions, as well as information about economic aspects, are allocated to the ICL and computer-aid processed to form plant-related Identification Numbers for each ICL and IC. The principles of evaluation are shown in **Figure 3.1.**

The computer-aided normalization and integration of original data generate numbers, which indicate the impact of treatment or disposal plants on the defined ICL level. To make different ICLs comparable, Prognos has created four assessment classes and assigned them values 3 - 2 - 1 - 0 respectively. The assigned points represent the ICL Identification Numbers. Two different types of evaluation point assignments were used to obtain the ICL Identification Numbers.

1. The ICL SR, OR, PQ, AR and AQ fall into a category where an optimal result, such as the 100 % mass conversion of waste to products, is possible (Maximum Available Standard)[10]. Data of these ICL are normed on the "Maximum Available Standard" which is defined as "1". Thus the calculated data represent the percentage of the "Maximum Available Standard" (relative numbers).

2. The other ICL (LV, WV, Ereff, WZ, WE, ÖZ) are evaluated relative to each other. The ICL data are normed on the value of the "Best Treatment Facility" from the total assessed plants (natural numbers) and therefore represent the percentage in reaching this "Best Treatment Facility". The definition of the borders for the classes, for relative and natural numbers, are shown in **Table 3.1.**

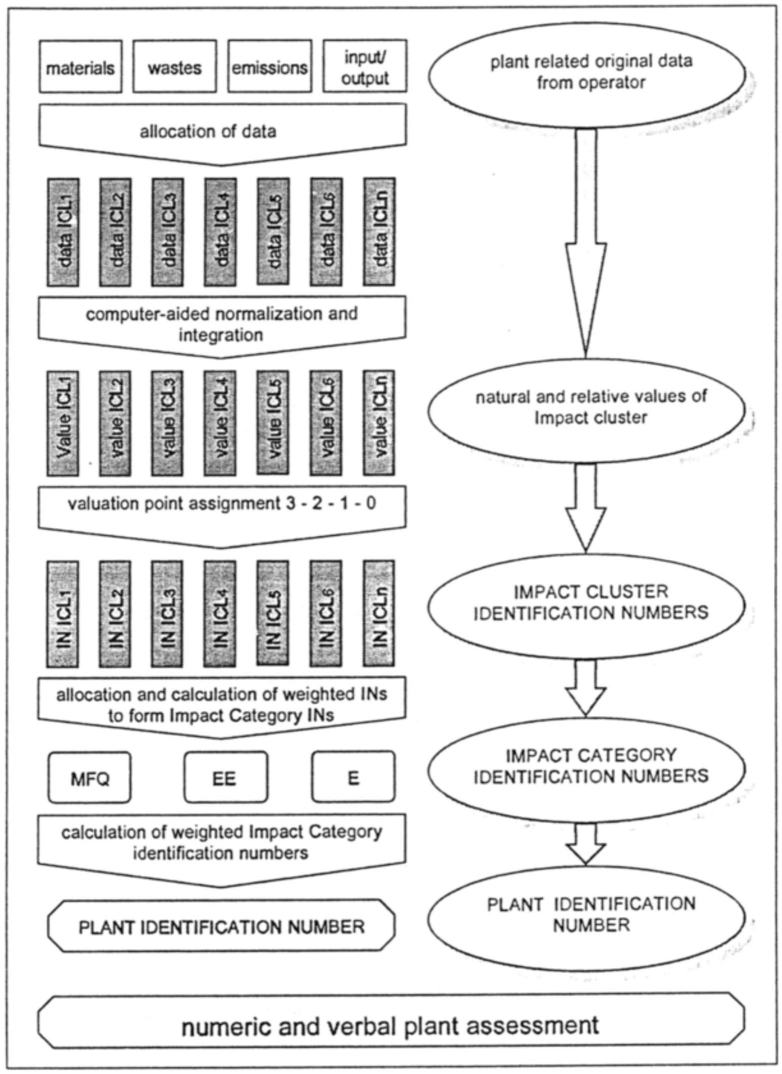
The ICL Identification Numbers are weighted and summed to get plant-related IC Identification Numbers. The weighting factors relate to the importance of the ICL in terms of material cycle, resource preservation and global significance [12]. The weighting factors are based on international discussion[11] (CML Leiden, SETAC) and expert reference groups (→ *Table 3.2* and *3.3*). The IC Identification Numbers are weighted and processed to form a Plant Identification Number.

[10]This Maximum Available Standard reflects an ideal yardstick.

[11]Criteria were, for example, the spatial relevance of environmental impacts. Environmental effects on a global scale were weighted more heavily than regional or local effects. The ecotoxicity and the human toxicity are the second most highly weighted because of their spatial and temporal relevance. The environmental impact of eutrophication, acidification and ozone creation were weighted less heavily in accordance with their occurance within waste disposal processes.

Table 3.1: Border definition for different classes and assigned values [11]; BTF = "Best Treatment Facility"-value

relative numbers	natural numbers	assigned points
< 0.1	> BTF + 1,000 %	0
0.1 to < 0.5	> BTF + 100 % to BTF + 1,000 %	1
0.5 to < 0.8	> BTF + 20 % to BTF + 100 %	2
0.8 to 1.0	BTF to BTF + 20%	3



ICL = impact cluster; MFQ = impact category Material Flow Quality; EE = Economic Efficiency; E = Ecology; IN = identification number

Fig. 3.1: Flow chart of principle assessment

Table 3.2: Impact Clusters, Indicators and weighting factors of the Impact Category Ecology [11]

impact-cluster	definition	indicator	weighting-factor
ÖZ gw	global warming	CO_2 (GWP)	**0.25**
ÖZ od	stratospheric ozone depletion	FCKW R 11 (ODP)	**0.15**
ÖZ oc	low-lying ozone creation	Ethylene (POCP)	**0.05**
ÖZ acid	acidification	NOx	**0.05**
ÖZ eutro	eutrophication	P	**0.05**
ÖZ toxai	air route toxicity	Cd	**0.1**
ÖZ toxwa	water route toxicity	Hg	**0.1**
ÖZ carc	carcenogenicity	PCDD/F	**0.25**

Table 3.3: Impact Cluster, Impact Categories and their weighting factors [11]

Impact cluster	definition	weighting factor	impact category
SR solid	substitution rate - solid /liquid products	**0.0125**	material flow quality (MFQ)/
SR gas	substitution rate gaseous products	**0.0125**	resource preservation, (20%)
WV	water consumption	**0.05**	
LV	air consumption	**0.025**	
EReff	effective energy usage	**0.1**	
OR	product output rate	**0.2**	MFQ/
PQ	product quality	**0.2**	cycle potential, (40%)
AR	waste output rate (incl. waste water)	**0.2**	MFQ / harmfulness, (40%)
AQ	waste quality	**0.2**	
WZ	normalized costs	**0.4**	Economic Efficiency (EE)
WE	economic benefits from products	**0.6**	
ÖZs	global warming, etc. (see *Table 2.1*)	**(1)**	Ecology (E)

4 Pilot Evaluation of Different Treatment Processes for Shredder Residues

In a study, Prognos assessed different options to treat shredder residues[12]. Shredder residue is a mass waste and often contaminated with heavy metals, hydrocarbons and especially polychlorinated biphenyl from treated electronic and automotive waste. Treatment plants for shredder residues must be able to mitigate the hazardous potential due to these contaminants, but must be competitive on the German recycling and disposal market.

[12]This research was part of a report submitted to the Hessian Ministry of Environment, on reduction and treatment potentials of wastes from shredder plants [13].

Prognos assessed the smoldering-burning technique (SIEMENS/KWU), the packed bed/dust pressure gasification (Sekundär-Verwertungs-Zentrum SVZ Schwarze Pumpe), a rotary furnace (Gesellschaft zur Entsorgung von Sondermüll in Bayern GSB) and a hazardous waste disposal site with leachate recovery and harnessing of digestion waste gas. **Table 4.1** shows the processed plant data of the ICs and the evaluation point assignment for further processing using **HoVe.**

Table 4.1: Plant related characteristic numbers, border definition and assigned points for evaluation

Impact Cluster	treatment / disposal plant SAV		FDV		SBV		SBV100		SAD		Border definition 0 - 1 - 2 - 3 points
	original number	points	original number	points	original number	points	original number	points	original number	points	
SRsolid	0 da OR=0	**0**	0.300	**1**	1.000	**3**	1.000	**3**	0 da OR=0	**0**	<0.1<0.5<0.8
SRgas	0 da OR=0	**0**	0.191	**1**	0.998	**3**	0.998	**3**	1.000	**3**	<0.1<0.5<0.8
OR	0.000	**0**	0.527	**2**	0.165	**1**	0.258	**1**	0.004	**0**	<0.1<0.5<0.8
PQ	0.000	**0**	0.153	**1**	0.033	**0**	0.052	**0**	0.001	**0**	<0.1<0.5<0.8
AR	0.310	**1**	-1.799	**0**	0.670	**2**	0.510	**2**	-0.980	**0**	<0.1<0.5<0.8
AQ	0.695	**2**	-0.352	**0**	0.899	**3**	0.857	**3**	-0.108	**0**	<0.1<0.5<0.8
WV	0.750	**2**	11.700	**0**	0.400	**3**	0.400	**3**	1.260	**1**	>4.0>0.8>0.48
LV	3500	**3**	11000	**1**	3084	**3**	3084	**3**	320	**3**	>30840>7168>3701
EReff	5600	**3**	12972	**1**	9542	**2**	16365	**1**	11970	**1**	>56000>11200>6720
WZ	3.200	**1**	1.000	**2**	0.832	**3**	0.832	**3**	1.000	**2**	>8.3>1.7>1.0
WE	0.0	**0**	715.0	**3**	54.0	**0**	137.0	**1**	0.0	**0**	<71.5<358<572
ÖZ gw	18.1E+3	**0**	-1.8E+3	**3**	595.8E+0	**0**	434.8E+0	**0**	318.2E+0	**0**	>-180>-900>-1440
ÖZ od	413.4E-3	**0**	325.6E-3	**0**	21.7E-3	**3**	-11.0E-3	**3**	21.8E-3	**3**	>217E-3>43E-3>26E-3
ÖZ oc	1.8E-9	**3**	7.1E-3	**0**	000.0E+0	**2**	000.0E+0	**2**	4.3E-3	**0**	>18E-9>3.6E-9>2.2E-9
ÖZ acid	2.3E+0	**0**	1.2E+0	**0**	2.2E-3	**3**	-217.0E-3	**3**	125.0E-3	**0**	>122E-3>4.4E-3>2.6E-3
ÖZ eutro	000.0E+0	**2**	16.7E-3	**2**	000.0E+0	**2**	000.0E+0	**2**	11.3E-3	**3**	>113E-3>23E-3>14E-3
ÖZ toxair	459.4E-6	**1**	3.6E-3	**0**	73.7E-6	**3**	74.0E-6	**3**	211.3E-6	**1**	>737E-6>147E-6>88E-6
ÖZ toxwa	15.0E-6	**1**	178.6E-6	**0**	000.0E+0	**3**	000.0E+0	**3**	1.5E-3	**1**	>150E-6>30E-6>18E-6
ÖZ canc	91.9E-6	**3**	1.1E-3	**0**	6.5E-6	**2**	6.5E-6	**2**	41.9E-6	**0**	>65E-6>13E-6>8E-6

* if ÖZ-numbers = 0 then 2 points are assigned
* SBV100 as scenario not integrated in border definition
SAV = rotary furnace, hazardous waste incineration GSB
FDV = packed bed/dust pressure gasification, Sekundär-Verwaltungs-Zentrum, Schwarze Pumpe
SBV = smoldering-burning technique, Siemens/KWU
SBV100 = smoldering-burning technique; scenario 100% shredder residues
SAD = disposal in compliance with TA-Abfall

Other treatment and disposal options for shredder residues that are still in the development stages, such as the disposal of modified residues as mining stowage, various mechanical treatment processes, or pyrolytic processes, and were not analyzed.

5 Higher Quality Treatment Plant for Shredder Residues

Table 5.1 shows the results, i.e. the IC Identification Numbers, for the different plants. Prognos has run different tests of normalization and weighting factors to prove the HoVe method. Different weighting slightly changed the single values of IC and ICL, but had no effect on the facilities ranking.

coal and input wastes into synthetic gas consumes a great amount of energy. Moreover the synthetic gas ranks low in the product refining chain and therefore devalues the IC Identification Number Material Flow Quality of the packed bed/dust pressure gasification plant. The emissions of the packed bed/dust pressure gasification adhere only to less strict threshold values and this causes a devaluation in the IC Ecology. Only the profit of selling the synthetic gas acts as an indicator for higher product quality and improves the plant evaluation.

The rotary furnace could not be highly rated by HoVe. It has only a slight effect on resource preservation and does not contribute to a closed cycle of materials. But it shows an energy efficient way to reduce the amount and harmfulness

Table 5.1: Impact Category Identification Numbers and Plant Identification

Impact Category Category	weighting factor	treatment / disposal plant SAV	FDV	SBV	SBV100	SAD	max. points
Material Flow Quality	0.35	35.8	25.0	54.2	50.8	8.8	100.0
Economical Efficiency	0.30	13.3	86.7	40.0	60.0	26.7	100.0
Ecology	0.35	21.7	28.3	68.3	68.3	31.7	100.0
Plant Identification Number	= 1.0	**24.1**	**44.7**	**54.9**	**59.7**	**22.1**	100.0

In the HoVe evaluation of the different treatment and disposal plants for shredder residues, the smoldering-burning technique rates as the comparably "high quality" technique. Especially in the ICs Material Flow Quality and Ecology it obtains the highest scores. The technique's emissions fall below the strict threshold values of the 17th Directive of the Federal Ambient Pollution Control Act and the plant operates without producing waste water, so that it is relatively highly rated in the IC Ecology. Only the resulting emission of CO_2, which contributes to the ICL General Warming Potential, causes a lower rating.

According to the German definition in waste management, the smoldering-burning technique does not produce "products" other than electric energy, so the plant could not be absolutely positively assessed in the IC Material Flow Quality. But because it produces only small and relatively harmless amounts of residues compared to other facilities, and because the residues are moreover defined as "residues for recycling" under German law, the smoldering burning technique has a high ICL Identification Number for *Waste Quality Rate*. Finally it rates comparably highest in the IC Material Flow Quality.

The packed bed/dust pressure gasification was not highly ranked in HoVe's ICs Material Flow Quality and Ecology. It produces a methane-rich synthetic gas, which is officially defined as a recycling product. But the conversion of soft

of the residual waste, as expressed in the IC Material Flow Quality.

HoVe also showed that the disposal site, even with leachate recovery and harnessing of digestion waste gas, is not environmentally sound and thus is not a "high quality" disposal option for shredder residues. It has comparably low emissions, but does not use most of its waste material and energy content. Moreover nearly half of the mass cannot be decomposed and therefore must be considered as residual waste.

6 Conclusions

The pilot study shows that HoVe enables a comparative assessment of treatment and disposal plants, that takes material flow, ecological and economic aspects into account. The method thus allows a definition of "high quality" treatment plants that adheres to the requirements of the German KrW-/AbfG. HoVe's allocation of facilities' impact into three Impact Categories allows a readily comprehensible assessment of different treatment and disposal options. Because these categories are in direct alignment with the KrW-/AbfG's differentiation between resource conservation, environmental impact and economic feasibility, interpretation of the results and comparative evaluation of different treatment or disposal concepts is facilitated. For example, HoVe

enables a comparative analysis of facilities for energetic recovery and material recycling. The numerical results of the pilot study correlate with the advantages and disadvantages of different techniques. Furthermore, because Prognos integrated the government, the plant operators and the disposers in the evaluation process of the pilot application HoVe achieved a high acceptance level, despite unfavorable evaluation of some of the plants.

In contrast to complete LCAs HoVe delivers a time and cost efficient evaluation of different options using existing data. The evaluation procedure may be easily modified for different applications. For example the emissions from waste transport or energy saved by not producing primary goods might be added as modules. The normalization and weighting factors used by HoVe were the result of expert round tables and based on the international discussion. Further applications, in particular evaluations of different technical concepts, should be made to further test the validity of these factors. HoVe's normalization and weighting factors could serve as a normative base for other evaluations made in accordance with the KrW-/AbfG.

HoVe acts in a sensitive field of environmental and political decisions, that includes the question of assigning wastes for recycling or disposal, a question that dominates the current discussion in German's waste policy [14]. The requirements of the KrW-/AbfG to select "environmentally sound" and "high quality" treatment and disposal technique makes the question of assigning wastes to either recycling or disposal obsolete. With the definition of these terms, HoVe delivers a concept to fulfill the demands of the KrW-/AbfG. With HoVe's contribution, the waste market can develop more economic competitiveness and more towards environmental sustainability.

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Life Cycle Assessment of Municipal Waste Water Systems

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Life Cycle Assessment was applied to municipal planning in a study of waste water systems in Bergsjön, a Göteborg suburb, and Hamburgsund, a coastal village. Existing waste water treatment consists of mechanical, biological and chemical treatment. The heat in the waste water from Bergsjön is recovered for the district heating system. One alternative studied encompassed pretreatment, anaerobic digestion or drying of the solid fraction and treatment of the liquid fraction in sand filter beds. In another alternative, urine, faeces and grey water would separately be conducted out of the buildings. The urine would be used as fertilizer, whereas faeces would be digested or dried, before used in agriculture. The grey water would be treated in filter beds. Changes in the waste water system would affect surrounding technical systems (drinking water production, district heating and fertilizer production). This was approached through system enlargement. For Hamburgsund, both alternatives showed lower environmental impact than the existing system, and the urine separation system the lowest. Bergsjön results were more difficult to interpret. Energy consumption was lowest for the existing system, whereas air emissions were lower for the alternatives. Water emissions increased for some parameters and decreased for others. Phosphorous recovery was high for all three alternatives, whereas there was virtually no nitrogen recovery until urine separation was introduced.